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(54) Abstract Title

Induction cooking hob

(57) An induction heater F1 for a cooker hob with a number of inductances L1, L'1 supplied from generators G1, G2 controlled by a controller CU and operating at the same frequency or harmonics of that frequency. In a low power operation (see fig 1) the inductance L1 alone is used to heat the induction heater F1 from generator G1 with the second generator G2 being used to heat an inductance L2 in a second induction heater F2. In high power operation the controller CU actuates a switch K1 to supply power from generator G2 to the inductance L'1 in the first induction heater. Operating the generators at the same or harmonic frequencies avoids beat frequencies and allows the use of modular low power generators. In an alternative embodiment (see figs 2 and 2a) the inductances L1 and L'1 can be connected in series so that currents flowing through the inductances are identical. In a further improvement the number of capacitors used in the circuit can be reduced with the series connection (see fig 3 and 3a). The heater capacity can be extended further by increasing the number of inductances and generators in the heater and operating each of the inductances independently (see figures 4 and 5) with an adjustable duty cycle for a pulse width modulation (PWM) control.

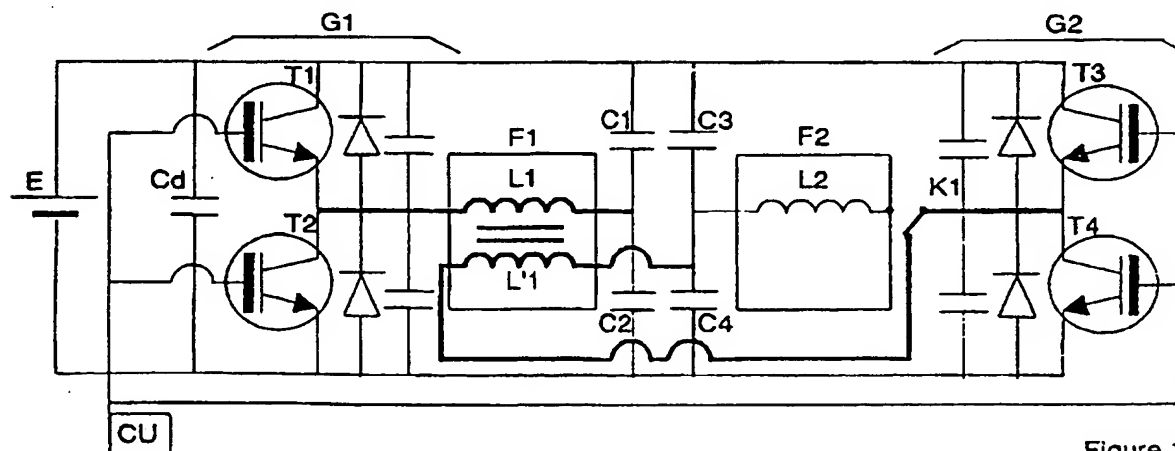


Figure 1A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

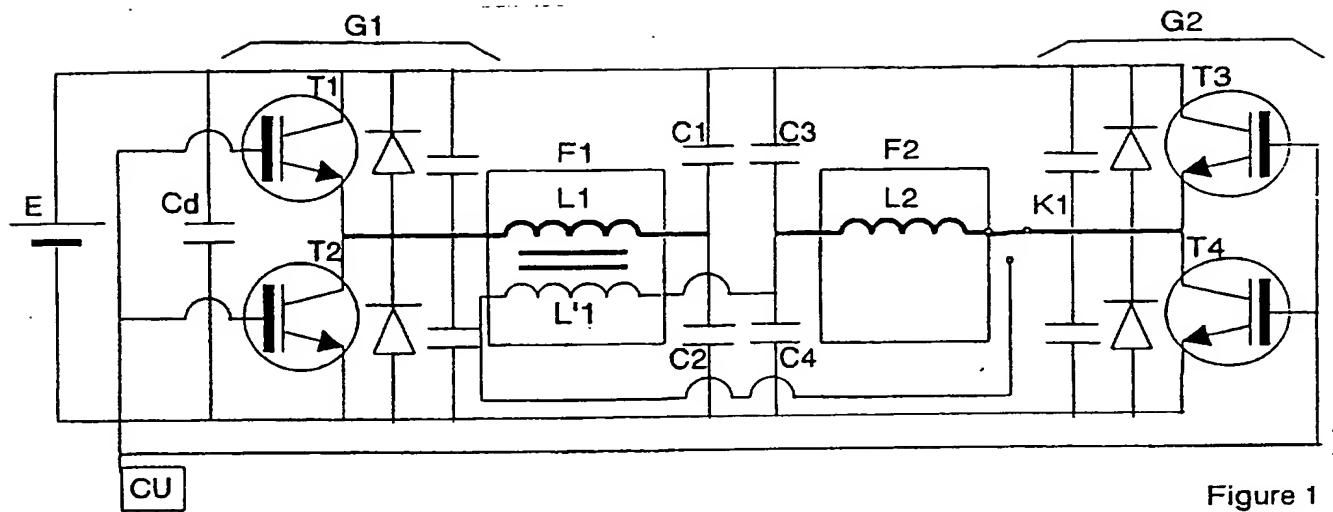


Figure 1

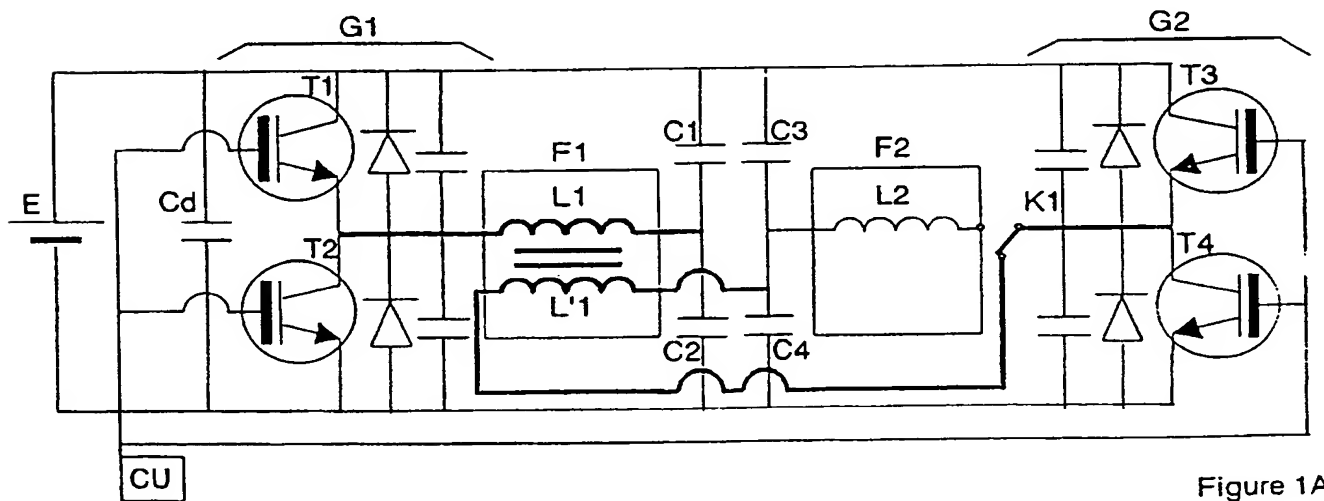


Figure 1A

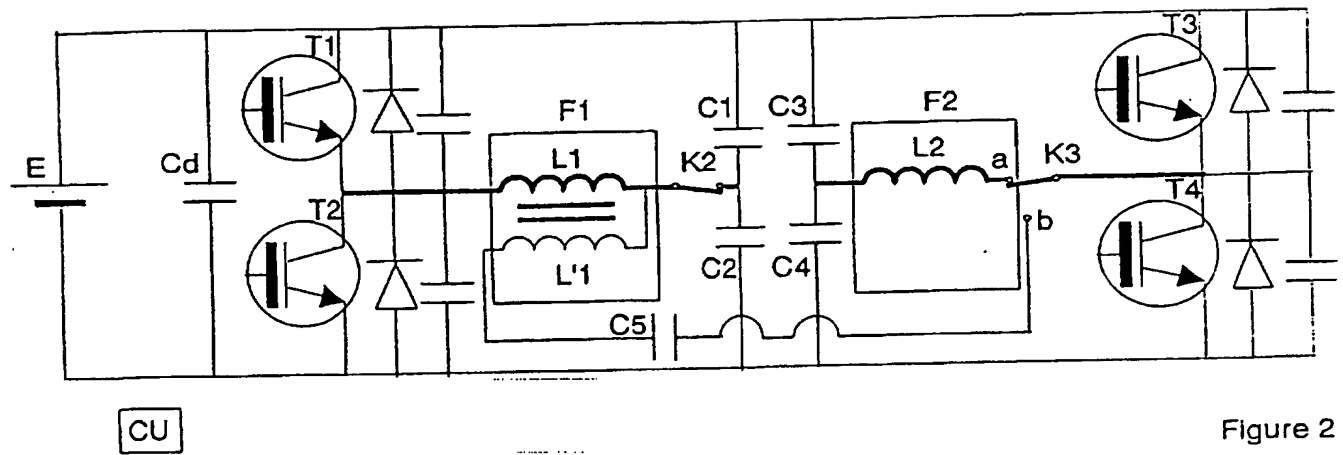


Figure 2

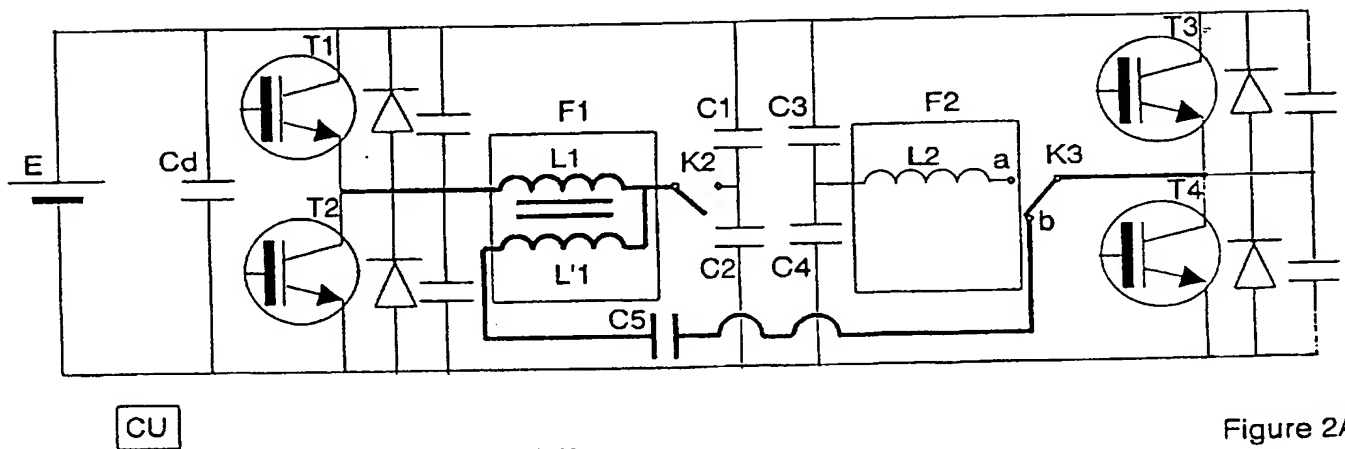


Figure 2A

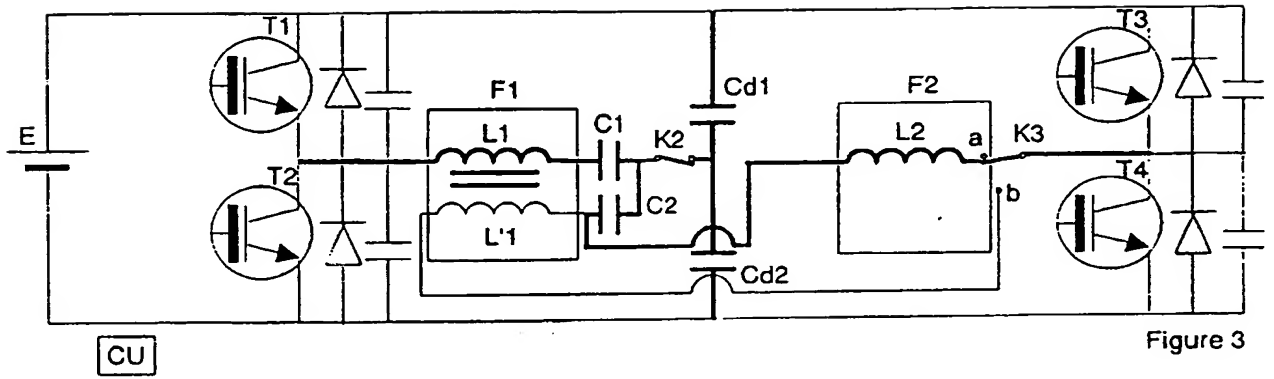


Figure 3

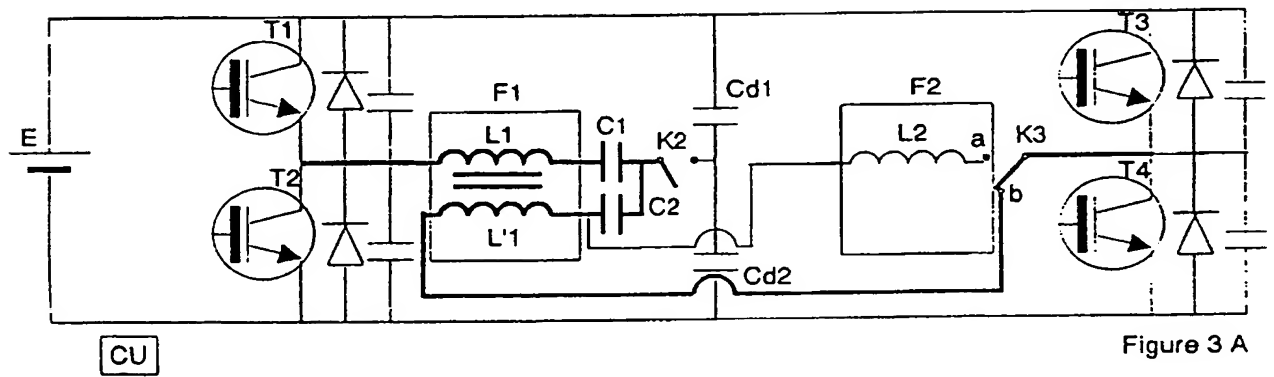


Figure 3 A

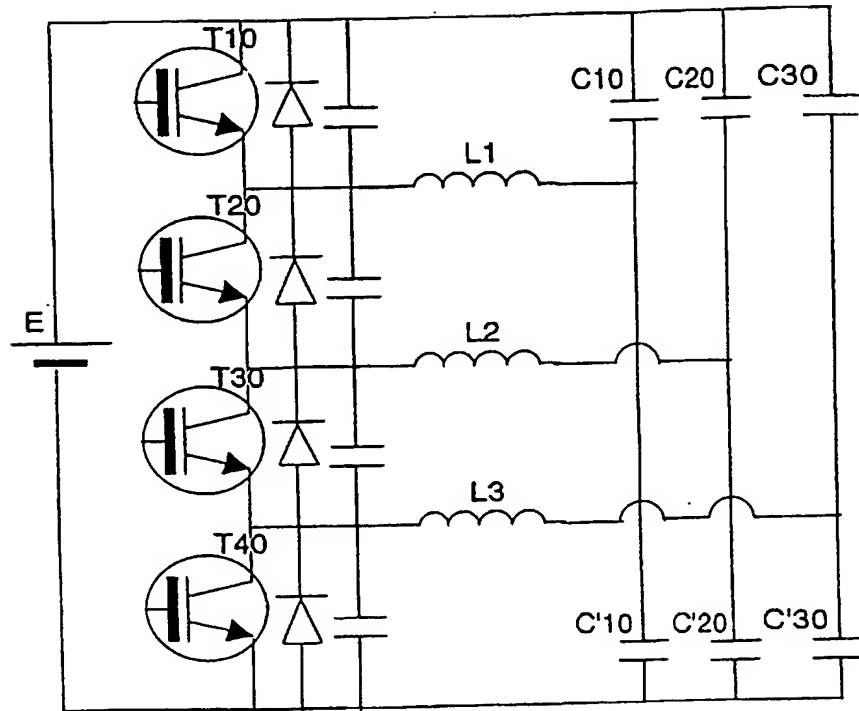


Figure 4

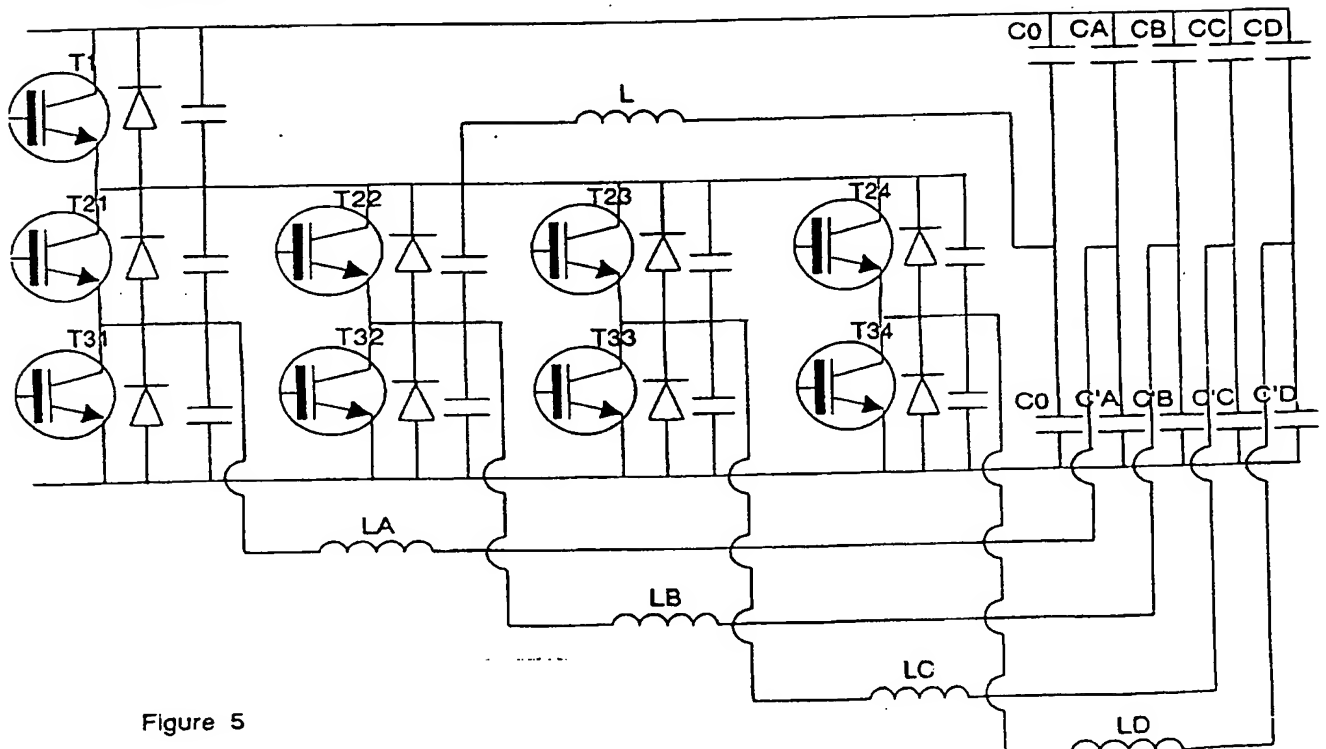


Figure 5

An Induction Cooking Hob

This invention concerns an induction cooking hob comprising induction heaters fed by generators.

Induction cooking, or more generally induction heating, uses eddy currents induced in the part to be heated by a high frequency magnetic field, the part being of an electrically conducting material. This part is, for example, a saucepan. The magnetic field is generated by an inductor supplied with a high frequency alternating current by a generator which sets the frequency and amplitude of the current as a function of the heating required. The frequency used for heating depends on a certain number of parameters and in particular the relative magnetic permeability μ_r of the receptacle and its electrical conductivity σ . Starting from the skin thickness, which one takes for example to be equal to half the thickness of the bottom of the receptacle to be heated, one then determines the angular frequency ω by using the formula:

20

$$\delta = \sqrt{\frac{2}{\mu_0 \cdot \mu_r \cdot \sigma \cdot \omega}}$$

from which one deduces the frequency by the formula:

25

$$f = \omega / 2\pi$$

One thus obtains an optimum frequency to be used, of the order of 10 to 50 kHz.

The generator is fed from an electrical supply whose voltage is rectified and filtered. The generator supplied with this rectified voltage U is generally a resonance generator. In effect, the inductors are typically
 5 implemented by winding an electrical conductor in a spiral so that, at the operating frequency, the applied load presents this inductor with a resistance R compatible with the power $P = U^2/R$ to be transmitted to the load. These same inductors are generally isolated mechanically,
 10 electrically and thermally from the load to be heated, which entails an air gap of several millimetres between the load and the inductor. At this distance and in this range of frequencies, the impedance $Z = R + j.\omega.L$ of the loaded inductor is strongly reactive, which entails an
 15 inductor quality factor $Q = L.\omega/R \gg 1$. It then suffices to add one or more capacitors C to the inductor, whose inductance is L , to form a circuit resonant at a frequency:

20
$$f = \frac{1}{2\pi\sqrt{LC}}$$

For this reason, the generators are mainly resonance inverters. The impedance Z and in particular the inductance L of the inductor depend on the characteristics
 25 of the load. The operating frequencies for a cooking hob with several heaters are in general not identical but close to each other. This phenomenon is on the other hand accentuated by the fact that to retain soft switching modes, power adjustments are generally made by adjusting
 30 the operating frequency and therefore two heaters intended to heat identical loads at different powers will use

different frequencies. It must be noted that this method of adjustment has the disadvantage of forcing the inverter to operate at frequencies far from its natural resonant frequency, which causes high losses. The best compromise
 5 is to have dual thyristor operation while working for maximum power as close as possible to the resonance which is the lowest working frequency and to increase the operating frequency to reduce this power.

10 These neighbouring frequencies produce beat frequencies which are transmitted to the receptacle being heated and which, owing to their small difference, are in the audible range (a few Hz to a few kHz). These beat frequencies, apart from the noise that they generate in
 15 the loads, cause difficulties in the control of independent generators.

To avoid this phenomenon which, because of its amplitude, can make using the product very inconvenient,
 20 it is necessary to maintain a good separation between the different generator - induction heater pairs, which is a major drawback for product modularity; for the same reason, it is for example impossible to heat a large saucepan on several neighbouring heaters fed by different
 25 generators.

One known solution consists of supplying neighbouring heaters cyclically for a period varying from a second, for mechanical switching devices, to ten or so milliseconds,
 30 for completely electronic solutions. In both cases, the generators must be designed with excess power capacity since power is not transmitted continuously to the heater

but is alternating, with a duty cycle which varies according to the power levels demanded from each heater connected to the generator. Furthermore, this cyclic supply can be felt to be a nuisance in use of the device because of the harsh power variations in the load if the period is of the order of a second, or because of the noise related to switching if this period is of the order of a few milliseconds, which corresponds to frequencies of a few hundred hertz.

10

Another known solution in the field of control and power electronics is to supply the inductors at the same frequency by using generators with hard switching, for example a chopper whose power adjustment method can then be at a fixed frequency in pulse width modulation (PWM) mode. It is however not prudent to use this type of generator to supply standard inductors, in particular because of the high quality-factor of the coils at the operating frequency. In effect this leads to difficulty in making current flow in inductive coils (saw-tooth currents) and major losses when the current in these coils is cut, which requires very large over-capacity in the power generator.

25 This invention aims to solve these problems and sets out to develop an induction cooking hob having low and high power and, in general, an induction heating device operating at a single frequency or at multiple frequencies to avoid beat frequencies and above all allowing the use of low power generators and in particular modular generators.

To this end, the invention concerns a cooking hob of the type defined above, characterised in that the inductors that are neighbouring or constituting the same heater are fed at the same frequency or at multiple
5 frequencies and in that it includes at least one high power heater comprising at least two inductors having a quasi identical on-load impedance returned to these inductors whatever the load put on this heater. A single
10 controller then governs the generators which operate in resonant mode with soft switching.

Advantageously, this cooking hob includes two induction heaters equipped with inductors, at least one of the heaters (first heater) being high power with at
15 least two inductors having a quasi identical on-load impedance at maximum load whatever the nature, shape and position of the load placed on this heater. An inverter generator is associated with each heater and operates with soft switching, a single controller governing the two
20 generators. A switching device is associated with the generator of the second heater and has two states:

- a normal state for which the switching device connects the generator to the inductor of the second heater,
- 25 • a power state in which the switching device connects the generator of the second heater to the second inductor of the first heater.

The resonance inverter generators, when they are
30 synchronised in frequency, allow implementation of a high power heater with particularly economical low power generators since they are operating continuously in soft

switching mode. A switching device allows the power from two or more generators to be routed to different heaters but it is quite possible to not use this switching device and to permanently connect several generators to one
5 heater, thus increasing its power.

Thanks to the switching device, the cooking hob allows advantage to be taken of the fact that in everyday use of the equipment, it is not necessary for the user to
10 continuously have high power available as much as with induction systems where the power is transmitted directly to the load. The efficiency is particularly high. These power levels are useful during special, short duration preparation sessions (boiling water, heating large
15 quantities of liquid, getting a large grill up to temperature). In continuous use, the power levels needed to maintain cooking (keeping on the boil, simmering) are most often low and can be provided by a single generator.

20 In this cooking hob, the two heaters can each be formed by two or more inductors having, for each heater, a quasi identical on-load impedance on its inductors; since each heater is associated with a generator, switching devices allow generators of other heaters to be connected
25 to the inductors of the same heater to thus have available high power supplied by several low-power generators and not by a single high-power generator. This allows in particular modular, large-scale fabrication of low-power resonance inverter generators which are moreover usable in
30 numerous other fields.

The market for power electronics and frequency converters is booming and certain applications are or will shortly be produced by the million for use as frequency converters for control of motors or power supplies intended for microwave oven magnetrons for example. It is thus economically very interesting to be able to benefit from this scale effect, either on the power components or on the control microprocessors, or on the generators themselves. Major production runs are carried out on low-power converters. The implementation method described allows the use of generators with various power capacities by coupling these low-power converters to heaters in which the power will be equal to the sum of the power capacities of the converters connected to the heater.

The frequency of the different generators connected to a heater must therefore be identical or a multiple of one and the same frequency. The phase of the different generators is in general zero (generators in phase) but it can be advantageous to run the generators in phase opposition in order to accumulate the magnetic flux from neighbouring inductors, which also has the effect of reducing the magnetic field in the immediate vicinity of the inductors. In the case of inductors combined to form the same heater and each having a quasi identical impedance on load, if the same number of combined inductors is in phase and in opposition, then the heater will generate a magnetic field and therefore quasi zero power. By varying the respective phases of the generators connected to the heater from 180° to 0° , it is very easy to achieve variance in the heater power from 0 to the total power of all the generators connected to the heater

when they are all in phase. This is particularly interesting since power adjustment can then occur at a fixed frequency which can be chosen to be sufficiently close to the natural resonance of the converter so as to minimise losses in the latter. Power adjustment is much finer since it is difficult to increase the generator operating frequency indefinitely in relation to its natural resonance to reduce the power and, below a certain power, chopping techniques have to be employed to reach sufficiently low power levels. Finally, to cancel out the field of an inductor by controlling the converters connected to it can also be of particular interest with the aim of minimising the leakage magnetic field in the case of inductors not coupled or badly coupled to loads.

According to other advantageous characteristics:

- the hob has several low-power generators connected to one or more inductors;
- the single controller has a sensor detecting the presence of a load on the inductor to authorise its supply by one or more generators;
- the single controller controls the neighbouring inductors so that their electromagnetic fields produce a cumulative flux between the inductors and under the load;
- the single controller controls the inductors of the same heater by adjusting the relative phase of the currents supplied by the generators associated with these inductors within a phase shift range between 0° and 180° , in order to adjust the heater power or limit its radiation;

- the hob is formed from mass-produced, low-power generators with devices allowing them to be associated and form high-power heaters;
- the induction coils are capable of withstanding high temperatures and are arranged as closely as possible to the load while being electrically isolated from it so that the resistance of the coil on load is high considering its inductance;
- the generator includes a decoupling capacitor which is split so as to create a quasi fixed capacitive voltage divider;
- the switching device comprises a changeover switch to connect the generator of the second heater to the second inductor of the first heater;
- the switching device includes a break switch between the junction point of the inductances of the first heater and the capacitors of the resonant circuit of the first inductance of the first heater to close (open) the resonant circuit of the first inductor of the first heater and a changeover switch to connect the inductor of the second heater to its generator or to connect the second generator to the second inductor of the first heater, in series with the first inductor of this first heater and in series with a common capacitor.

This invention will be described below in a more detailed manner with the aid of appended diagrams in which:

- Fig. 1 is a diagram of the first implementation method for a cooking hob with two heaters according to the invention, in normal and independent operation of the two heaters,

- Fig. 1A shows the diagram of Fig. 1, in power operating mode on the heater composed of combined inductors having an identical on-load impedance,
- Fig. 2 shows a diagram of a first variant of the implementation of a two-heater cooking hob, in normal and independent operation of the two heaters,
- Fig. 2A shows a diagram of the cooking hob of Fig. 2 in power operating mode,
- Fig. 3 shows a diagram of a second variant of the implementation of a two-heater cooking hob according to the invention, in normal operating mode,
- Fig. 3A shows a diagram of the cooking hob of Fig. 3 in power operating mode,
- Fig. 4 shows a method for implementation of a cooking hob with three heaters having one impedance on whatever load,
- Fig. 5 shows a generalisation of the cooking hob of Fig. 4 able to work with several inductors having one impedance on any load.

According to Fig. 1, the invention concerns an induction cooking hob not shown, with two heaters F1, F2. One of the heaters, F1, or the first heater is designed to supply a high power while the other heater F2 is only designed to supply medium power.

High-power heater F1 has two inductors L1, L'1 having a quasi identical on-load impedance on these inductors. This identical on-load impedance is obtained by the design of the inductors, not described here. This on-load

impedance is the same whatever the nature, shape and position of the load, that is to say utensil to be heated, placed on heater F1 equipped with its two inductors.

5 These heaters are supplied with high-frequency current, as generally known, from a DC source shown diagrammatically by E. This source in fact represents a rectifier and filter assembly connected to the mains supply and providing on its output a rectified voltage
10 with a DC component.

 This DC supply feeds the two resonance inverter generators G1, G2. Generator G1 is associated with heater F1 and generator G2 with heater F2. These generators
15 operate with soft switching. They each comprise two transistors T1, T2 or T3, T4, provided in the usual manner with unreferenced diodes and capacitors. These generators each supply an oscillator circuit formed from inductance and capacitance. The load resistances "seen" by the
20 inductors are not shown and are implicitly included in the Li terms, in series with the resistances.

 Generator G1 oscillator circuit is formed by the inductance L1 of inductor I₁ of heater F1 and charge
25 capacitors C1, C2. _____

 Generator G2 oscillator circuit is formed by the inductance L2 of inductor I₂ of heater F2 and charge capacitors C3, C4.

30

Transistors T1, T2 and T3, T4 of the two generators G2, G1 are connected to a single controller CU which operates them independently or in synchronism.

5 Power heater F1 comprises two inductors L1, L'1 combined so that their on-load impedances are identical; their coupling is shown in Fig. 1.

Power supply E is decoupled by a decoupling capacitor
10 Cd.

The circuit also has a two-state switching device, a normal and a power state. In the example, the switching device is formed by a two-position changeover switch K1
15 associated with generator G2 of the second heater F2. This changeover switch K1 can go into the normal state (Fig. 1) in which it closes the generator G2 circuit as the latter is then connected to inductance L2 of inductor I, and allows heater F2 to be supplied. This changeover switch K1
20 can also change to a second state or power state (Fig. 1A) in which it ensures connection of inductance L1' of the first heater F1, so that in this position the inductance L1 is fed by generator G1 and inductance L'1 by generator G2, inductance L2 of the second heater F2 being
25 disconnected. As it is assumed that in this second position the impedances and therefore the inductances L1 and L'1 are identical on load, the two inductors I₁, I'1 of heater F1 will be able to be controlled in synchronism and work in a synchronous manner in soft switching mode.
30

The two generators supply power variable between zero and an equal or different maximum power P for the two in

the normal position, when changeover switch K1 ensures connection of inductor I_1 , heaters F1 and F2 can both receive a power going as far as maximum power P from each of the generators G1, G2 to which they are independently
 5 connected. The two generators can also be designed for different power capacities.

In the second state, namely power, heater F1 receives double power, being able to go up to the maximum power 2P.
 10

It should be noted that since inductances L_1 , L_1' are coupled by their arrangement in their heater F1 inductor, it is necessary for the current flowing in them to be synchronous. This is assured by the single controller CU
 15 for the two generators G1, G2 and by the fact that the load applied to them is the same.

This circuit in Fig. 1 can be generalised to a number (n) of inverters allowing transmission to a heater of a
 20 power going from 0 to n.P. As already mentioned above, this allows implementation of a high-power heater with low-power generators. By way of example, for certain professional uses, heaters with a power of the order of 7 to 8 kW are necessary. One can thus implement a heater
 25 with a power of 7.2 kW by using four generators each having a power of 1.8 kW connected to a heater which has four linked inductors. This circuit is also applicable to combinations of linked inductors, the latter then having to have an identical or multiple on-load impedance so that
 30 the operating frequencies of the different generators are identical or multiple. In the case of (n) inverters, the latter can also advantageously have (n') switching devices

so that in the power position, a heater can receive power from (n) generators or several heaters can receive a power higher than the power from a single generator and that in the normal position, the (n) generators each feed a heater
5 on the induction cooking hob, certain heaters being able to operate continuously with several generators.

The diagram in Fig. 1 can also be generalised to be completely symmetrical, that is to say to have two heaters
10 each with two inductors so as to allow the independent supply to each of the heaters with its generator and the use of only one of the two inductors or to connect the two generators to the two inductors of the same heater. This can be necessary in certain configurations of heating
15 surfaces to have powerful heaters at the front of the heating plate and not solely at the back as is the case traditionally.

As cooking hobs have four heaters in general, it is
20 in effect sufficient to propose two potentially very powerful heaters. Temporary stoppage of the front heater during use of the rear heater on high power is not harmful inasmuch as the power of each generator is relatively high for example (1400 to 1800 W maximum) and there are two
25 additional heaters still available on the cooking hob. Finally, this is particularly interesting since the surfaces of the heaters are different and correspond better to normal use where one uses saucepans of different sizes, large ones on large heaters which can be very
30 powerful and small ones on small heaters whose power remains sufficient in relation to the size of the load to be heated.

In the circuit shown in Fig. 1, it is necessary for the loads to be very similar. This imposes obligations not only on the design of inductors I_1 , I_1' but also on the
5 tolerances of the resonance capacitors.

Fig. 2 shows a variant of implementation of the cooking hob according to the invention, allowing the constraints imposed on the circuit components to be
10 avoided.

Elements of this circuit that are identical to those of the Fig. 2 circuit have the same references.

15 This circuit is distinguished by an additional charge capacitor C5 and a switching device having a changeover switch K3 in addition to a break switch K2.

The two inductors I_1 , I_1' are overlapping in the same
20 way and a double line schematically shows their electromagnetic coupling in heater F1.

Break switch K2 can go into a closure position (Fig. 2) and an opening position (Fig. 2A). Changeover switch K3
25 can go into a position 'a' (Fig. 2) or a position 'b' (Fig. 2A).

Thus, depending on the position of break switch K2 and changeover switch K3, one can make the two heaters
30 operate separately by supplying each from its generator G1, G2 or make heater F1 operate at power by supplying it from the two generators G1, G2. In the first case, the

resonant circuits for heater F1 comprise inductance L1 and charge capacitors C1, C2 and for heater F2 comprise inductance L2 and charge capacitors C3, C4. When the two generators G1, G2 are connected to the two inductances I₁, I₁' of heater F1, the resonant circuit is formed by
 5 inductances L1, L1' in series with charge capacitor C5.

Fig. 2 shows, for the in full line position of the switching elements (break switch K2, changeover switch
 10 K3), the supply of inductor I₁ of heater F1 since the resonant circuit L1, C1, C2 is connected to the power supply and the operation of heater F2 since the resonant circuit L2, C3, C4 is connected to the power supply.

15 In this operating mode, the controls for the two inverters are independent as a function of the control orders and their respective loads; as for the diagram in Fig. 1, the operating frequencies are completely asynchronous, which necessitates a sufficient spacing
 20 between the two separate heaters.

Fig. 2A shows the position of the switching elements K2, K3 for operation of heater F1 on power, heater F2 being disconnected.

25 Break switch K2 and changeover switch K3 are in the following positions: break switch K2 is open and changeover switch K3 is in position b, putting in series the inductors (inductances L1 and L'1) with capacitor C5
 30 and breaking the resonant circuit of inductor I₂ of heater F2. The currents flowing in inductances L1, L'1 are then completely identical and are so whatever the tolerances on

the components, notably the resonance capacitors, as these inductances are fed in series.

The switching state of the two operating modes of the circuit in Fig. 2 is summarised as follows:

Normal state

Normal and independent operation of heaters F1 and F2:

10

L1 and L2: active

$L'1 = 0$

$K2 = 1$

$K3 = a$ (Fig. 2)

15

Power state

Operation of heater F1 at high power:

L1 and L'1: active

$L2 = 0$

$K2 = 0$

20

$K3 = b$ (Fig. 2A)

Fig. 3 shows a simplification of the circuit in Fig. 2, minimising the number of capacitors used.

25 In this variant, the same references as above will be used to designate the same elements.

The modification is in the transformation of decoupling capacitor Cd, which is separated into two capacitors Cd1, Cd2, forming a capacitive divider giving a quasi fixed voltage. For this, it is necessary to respect

30

the following conditions between the capacitances C_{d1} , C_{d2} , C_1 and C_2 :

$$\begin{aligned} & C_{d1} + C_{d2} \gg C_1 \\ 5 \quad & C_{d1} + C_{d2} \gg C_2 \end{aligned}$$

To separate the decoupling capacitor into two capacitors is particularly interesting to reduce the overall thickness of the generator.

10

As previously, this cooking hob can operate in normal mode with two independent heaters and in a mode with a single heater at high power.

15

These two modes are shown respectively for the position of break switch K_2 and changeover switch K_3 comprising the switching device in Fig. 3 and Fig. 3A.

20

Capacitor C_5 of the second variant (Fig. 2) does not exist in this case.

The two modes of operation are as follows:

25

Normal operating state (normal state) with independent heaters F_1 , F_2 :

30

Break switch K_2 is closed and changeover switch K_3 is in position a. Inductances L_1 , L_2 of the inductors of the two heaters F_1 , F_2 are connected separately, each to its generator G_1 , G_2 .

Inductance L'_1 is not connected.

The oscillator circuit of inductor I_1 put into operation alone for heater $F1$, is formed by inductance $L1$ and capacitors $C1$, $Cd1$, $Cd2$.

5

The oscillator circuit of generator $G2$ is formed by inductance $L2$ and capacitors $Cd1$, $Cd2$.

This mode of operation is represented as follows:

10

$L1$ and $L2$: active

$L'1 = 0$

$K2 = 1$

$K3 = a$ (Fig. 3)

15

The second operating state corresponds to operation of $F1$ alone at high power, heater $F2$ having no supply. Break switch $K2$ is then open and changeover switch $K3$ is in position b .

20

In this case, inductances $L1$, $L1'$ of inductors I_1 , I_1' of heater $F1$ are connected in series with capacitors $C1$, $C2$ and constitute the load on the H bridge formed by the two converter elements of $G1$, $G2$.

25

This mode of operation is represented as follows:

$L1$ and $L1'$: active

$L2 = 0$

$K2 = 0$

$K3 = b$ (Fig. 3A)

30

This circuit offers the advantage of appreciably reducing the overall volume of the capacitors for operation quasi identical to the preceding operation.

5 In general, circuits 2 and 3 do not make it obligatory to use particular inductors with an identical on-load impedance. It is then possible to extend the arrangement configurations of the inductors by implementing heaters of various shapes and dimensions by
10 associating elementary inductors. One can for example implement oblong heaters intended for fish hot-plates, these oblong heaters being formed for example from two heaters placed side by side. The operating frequency is then unique to the structures used.

15

This does however impose an identical current in these heaters and therefore the impossibility of adjusting the power of neighbouring heaters separately. It is however possible, by keeping a single frequency or
20 multiple frequencies, to adjust the power of neighbouring heaters separately and for this it is necessary to use particular structures, giving rise to the notion of a master generator and slave generators whose operation will be linked to the operation of the master.

25

Fig. 4 shows an implementation to supply, for example, three inductors I1, I2, I3 whose inductances L1, L2, L3 have some value or other.

30 This circuit can be used to feed 2 to n inductors; for 1 inductor, one thinks of a standard series resonance half-bridge.

The oscillator circuits are formed each time by inductances L1, L2, L3 and the associated capacitors (C10, C'10), (C20, C'20), (C30, C'30). This circuit includes
 5 several resonance inverters with a common basic frequency. One can think of different generators.

Thus, when transistors T30, T40 are cut off, inductance L1 is supplied via the half-bridge (T10, T20).
 10

When transistors T10 and T20 are cut off, transistors T30, T40 supply inductance L3. Finally, when transistors T10, T40 are cut off, inductance L2 is supplied via the half-bridge (T20, T30). One can also supply them
 15 simultaneously by controlling a master inductor and controlling the other inductors by the same voltage but with an adjustable duty cycle according to the technique of pulse-width modulation (PWM). In this case, one adapts the capacitance of the resonance capacitors so that all
 20 the break switches work according to a dual thyristor switching mode. In this case, one also has soft switching from a single frequency for nevertheless different loads associated with each of the inductors I1, I2, I3 which can be used simultaneously and placed in proximity to one
 25 another without the risk of generating beat frequencies while authorising different power levels on neighbouring inductors supplied by different inverters, the power settings being adjusted as a function of the pulse width (PWM). It will be noted that without employing this
 30 device, PWM chopper mode would lead to designing considerable over-capacity into the generator owing to the very inductive nature of the inductors. This very

inductive character can be alleviated by getting the inductor as close as possible to its load, indeed by replacing the glass of the ceramic hob by a more resistive material of less thickness, electrically isolating the
 5 inductor from its load.

Fig. 5 shows a variant of the circuit in Fig. 4 for a larger number of inductors to be controlled according to the same principle, with a master inductor and slave
 10 inductors, working in zero-crossing voltage switching operation (ZVS switching) for all generators supplying the slave inductors.

The circuit comprises a master circuit L, (C0, C'0) in the upper part and slave circuits formed by inductances
 15 LA, LB, LC, LD and associated capacitors (CA, C'A), (CB, C'B), (CC, C'C), (CD, C'D). Each oscillator circuit thus formed is controlled by changeover switches (T2i, T3i), (T21, T22, T23, T24 ... , T31, T32, T33, T34).

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Break switch T1 is controlled by a standard voltage and each of the arms T2i, T3i is controlled according to a variable duty cycle inside this voltage, separately adjustable for each generator.

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Switching conditions in ZVS mode are as follows:

- at the time a break switch T2i opens, the current Ii must be greater than 0,

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- to be able to open break switches T_{3i} (which must be opened simultaneously), it is necessary that $-I_0 > I_1 + I_2 + \dots + I_{i-1}$.

5 In parallel, one can generate the current I_0 in a fixed and controlled manner by supplying not an inductor but, for example, a pure inductance of fixed value; the peak values of the current will be fixed and calculated to allow ZVS switching of all the generators. This modular
10 structure is well adapted to controlling a system of inductors with a large number of winding elements. The power of each generator is then low.

 This structure according to the invention therefore
15 allows use, in the same cooking hob, of separate inductors and for them to be sufficiently close together for them to form a large cooking surface able to heat either a single large container at high power, or different containers at power levels which can be different. Since the "slave"
20 converters are low power, it is possible to use very economical components as indicated above, since they are used moreover in large-scale mass production.

CLAIMS

1 - Induction cooking hob with induction heaters supplied by generators,

5 characterised in that:

- the heaters have at least one inductor,
- neighbouring inductors or those in the same heater are supplied at the same frequency or at multiple frequencies.

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2 - Cooking hob according to claim 1, characterised in that:

- at least one of the heaters is high power and comprises at least two inductors having a quasi identical on-load impedance whatever the load put on this heater,
- generators controlled by a single controller(CU),
- generators operate in resonant mode with soft switching.

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3 - Cooking hob according to claim 1, with at least one generator, characterised in that:

- the generator comprises a master inverter supplying at least one power inductor or a pure inductor and at least one other inverter operating as a slave and connected to at least one inductor,
- the slave generator uses the frequency of the master generator,
- the power of the slave inverter is adjustable in PWM mode.

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4 - Cooking hob according to claims 1 and 2,
characterised in that:

- 5 - it includes at least two separate heaters and at
 least two generators and a two-state switching
 device (K) associated with one of these
 generators:
 - 10 - a normal state for which the switching device
 connects the second generator to the second
 inductor forming the second heater,
 - 15 - a power state for which the switching device
 connects the second generator to the second
 inductor of the first heater so as to
 increase the power of this heater, the
 controller(CU) controlling the two generators
 (G1, G2) to supply the two inductors (I1,
 I1') at the same frequency or a multiple
 frequencies.

20

5 - Cooking hob according to claim 1,
characterised in that:

- it has several low-power generators connected to
one or more inductors.

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6 - Cooking hob according to claims 1 and 2,
characterised in that:

- 30 - the single controller (CU) has a sensor detecting
 the presence of a load on an inductor to authorise
 its supply by one or more generators.

7 - Cooking hob according to claims 1 and 2,

characterised in that:

- the single controller (CU) controls the neighbouring inductors so that their electromagnetic fields produce a cumulative flux between the inductors and under the load.

8 - Cooking hob according to claims 1, 2 and 6, characterised in that:

- the single controller (CU) controls the inductors of the same heater by adjusting the relative phase of the currents supplied by the generators associated with these inductors within a phase shift range between 0° and 180° in order to adjust the heater power or limit the radiation from the heater.

9 - Cooking hob according to claim 1, characterised in that:

- it is formed from low-power generators which are mass-produced with devices allowing them to be associated and high-power heaters to be implemented.

10 - Cooking hob according to claim 1, characterised in that:

- the induction coils are capable of withstanding high temperatures and are arranged as closely as possible to the load while being electrically isolated from it so that the resistance of the coil on load is high considering its inductance.

11 - Cooking hob according to claim 1,
characterised in that:.....

- it includes a decoupling capacitor split to create
a quasi fixed capacitive voltage divider.

5

12 - Cooking hob according to claim 1, 2 and 4,
characterised in that:.....

- the switching device comprises a changeover switch
(K1) to connect the generator (G2) of the second
10 heater (F2) to the second inductor (F'1) of the
first heater (F1).

13 - Cooking hob according to claim 1, 2 and 4,
characterised in that:.....

- 15 - the switching device includes a break switch (K2)
between the junction point of the inductances (I1,
I'1) of the first heater and the capacitors (C1,
C2) of the resonant circuit of the first
inductance (I1) of the first heater (F1) to close
20 (open) the resonant circuit of the first inductor
of the first heater (F1) and a changeover switch
(K3) to connect the inductor (I2) of the second
heater (F2) to its generator (G2) or to connect
the second generator (G2) to the second inductor
25 (I'1) of the first heater, in series with the
first inductor (I1) of this first heater (F1) and
in series with a common capacitor (C5).

14 - Cooking hob according to claim 1,
30 characterised by:

- a decoupling capacitor (Cd1, Cd2) split to form a capacitive voltage divider giving a quasi fixed voltage,
- 5 - a capacitor (C1) in series with the first inductance (L1) of the first heater (F1) and forming, with the split capacitor, the oscillator circuit of the first inductance,
- 10 - a capacitor (C2) in series with the second inductance (I'1) of the first heater (F1),
- 15 - the circuit of the first inductor (I1) and that of the second inductor (I'1) connected after the two capacitors (C1, C2),
- 20 - the switching device comprising a break switch (K2) making (breaking) the link between the junction point of the circuits of the first and the second inductor (I1, I'1) with the quasi fixed voltage point of the divider and a changeover switch (K3) connecting the second generator (G2), either:
 - 25 - to the inductor (I2) of the second heater (F2) and to the capacitors (Cd1, Cd2) and by the closed break switch (K2) to capacitor (C1) and to the inductor (L1) of the first heater,
 - 30 - to the second inductance (L'1) of the first heater, in series with the first inductor (I1) and their capacitors (C1, C2), break switch (K2) having cut the link with the quasi fixed voltage point of the split capacitor.



Application No: GB 0008263.6
Claims searched: 1 to 14

29.

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Date of search: 4 July 2000

Patents Act 1977 Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:
UK Cl (Ed.R): H2H - HHJ
Int Cl (Ed.7): H05B - 6/02, 6/04, 6/06, 6/10, 6/12, 6/36, 6/44
Other: Online : WPI, EPODOC, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	US 5 808 280 A (Gaspard) column 3, lines 5 to 45	1,5,9
X	US 4 549 056 A (Okatsuka)	1
X	US 4 390 769 A (Steigerwald) column 3, lines 1 to 23	1,5

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.